A Project in the ITL Pervasive Computing Portfolio

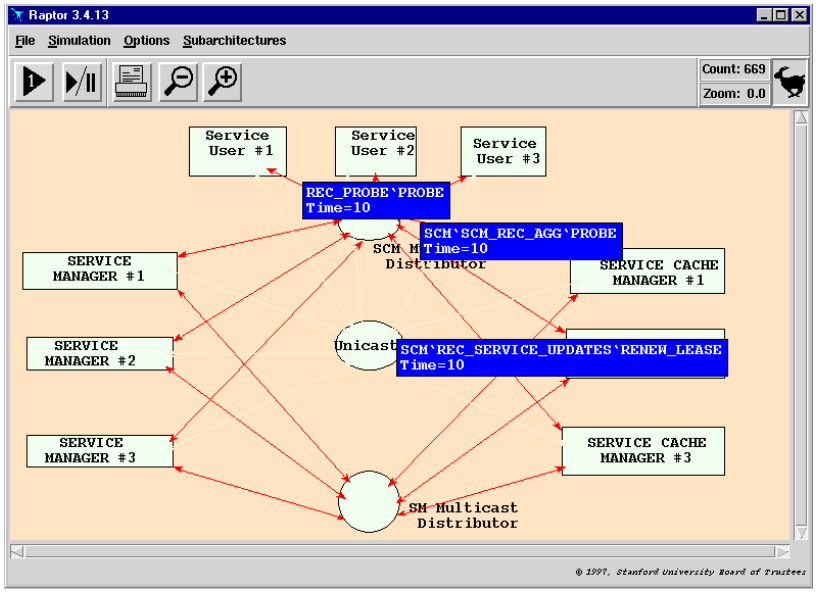
Defining a Technical Basis for Comparing and Contrasting Emerging Dynamic Discovery Protocols

Christopher Dabrowski
Software Diagnostics & Conformance Testing Division
cdabrowski@nist.gov

Kevin Mills
Advanced Networked Technologies Division
kmills@nist.gov

PC2001 Conference
May 2, 2001

Modeling Function, Structure, and Behavior



Objectives

(1) Provide increased understanding of the competing dynamic discovery services emerging in industry
(2) Develop metrics for comparative analysis of different approaches to dynamic discovery and assuring quality and correctness of discovery protocols
(3) Assess suitability of architecture description languages to model and analyze emerging dynamic discovery protocols

Technical Approach

- Develop ADL models from selected specifications for service discovery protocols and develop a suite of scenarios and topologies with which to exercise the ADL models
- Propose a set of consistency conditions & constraints that dynamic discovery protocols should satisfy
- Propose a set of metrics, based on partially ordered sets, with which to compare and contrast discovery protocols
- Analyze ADL models to assess consistency condition satisfaction, and to compare and contrast protocols

Status as of May 1, 2001

- Developed a generic UML model encompassing the structure and function of Jini, UPnP, SLP, Bluetooth, and HAVi
- Projected specific UML models for Jini, UPnP, and SLP
- Completed a Rapide Model of Jini structure, function, and behavior
- Drafted and implemented a scenario language to drive the Rapide Jini Model.
- Developed a set of consistency conditions and constraints for Jini behavioral model; currently being tested using scenarios.
- Discovered significant architectural issue in interaction between Jini directed discovery and multicast discovery

Products

- Rapide specifications of Jini, Universal Plug and Play (UPnP), and Service Location Protocol (SLP)
- Scenarios and topologies for evaluating discovery protocols
- Suggested consistency properties for service discovery protocols
- Suggested metrics, based on partially ordered sets (POSETs), for comparing and contrasting discovery protocols
- Paper identifying inconsistencies and ambiguities in service discovery protocols and describing how they were found
- Paper proposing consistency conditions for service discovery protocols, and evaluating how Jini, UPnP, and SLP fare
- Paper comparing and contrasting Jini, UPnP, and SLP at the level of POSET metrics

What is a dynamic discovery protocol?

Dynamic discovery protocols enable dynamic elements in a network (including software clients and services, as well as devices):

- **to discover each other without pre-arrangement,**
- **to express opportunities for collaboration, and**
- **to compose themselves into larger collections that cooperate to meet an application need.**

What about robustness in the face of change?

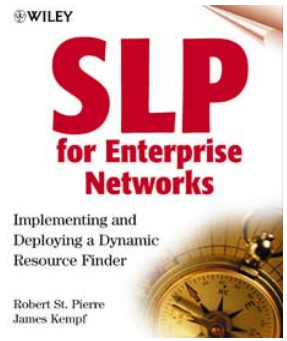
Discovery protocols contain logic intended to provide resilience in the face of process, node, and link failures of both a temporary and permanent nature.

Various Protocols for Dynamic Discovery are Emerging in the Commercial Sector

JINI

Universal

Plug and Play



The Salutation Consortium™

HAVi

Bluetooth™

Why are various dynamic discovery protocols emerging?

- **Some industry groups approach the problem from a vertically integrated perspective, coupled with a narrow application focus but targeting a different application domain. (e.g., HAVi, Salutation Consortium, and Bluetooth Service Discovery)**
- **Sun has designed Jini as a general service-discovery mechanism atop Java, which provides a base of portable software technology.**
- **Some suspect that the Jini approach will prove too inefficient for use in consumer appliances and in other low-cost, low-performance computing platforms; thus, some propose a different set of protocols.**

Our Motivation?

To provide industry with metrics to compare and contrast emerging dynamic discovery protocols and to strengthen the quality and correctness of those protocols.

Our General Approach?

1) **Use Architectural Description Languages (ADLs) and associated tools to analyze Discovery Protocol specifications assessing consistency and completeness w.r.t. conditions of dynamic change.**
2) **Compare and contrast emerging commercial service discovery technologies with regard to function, structure, behavior, performance and scalability in the face of dynamic change.**

Particulars of Our Approach

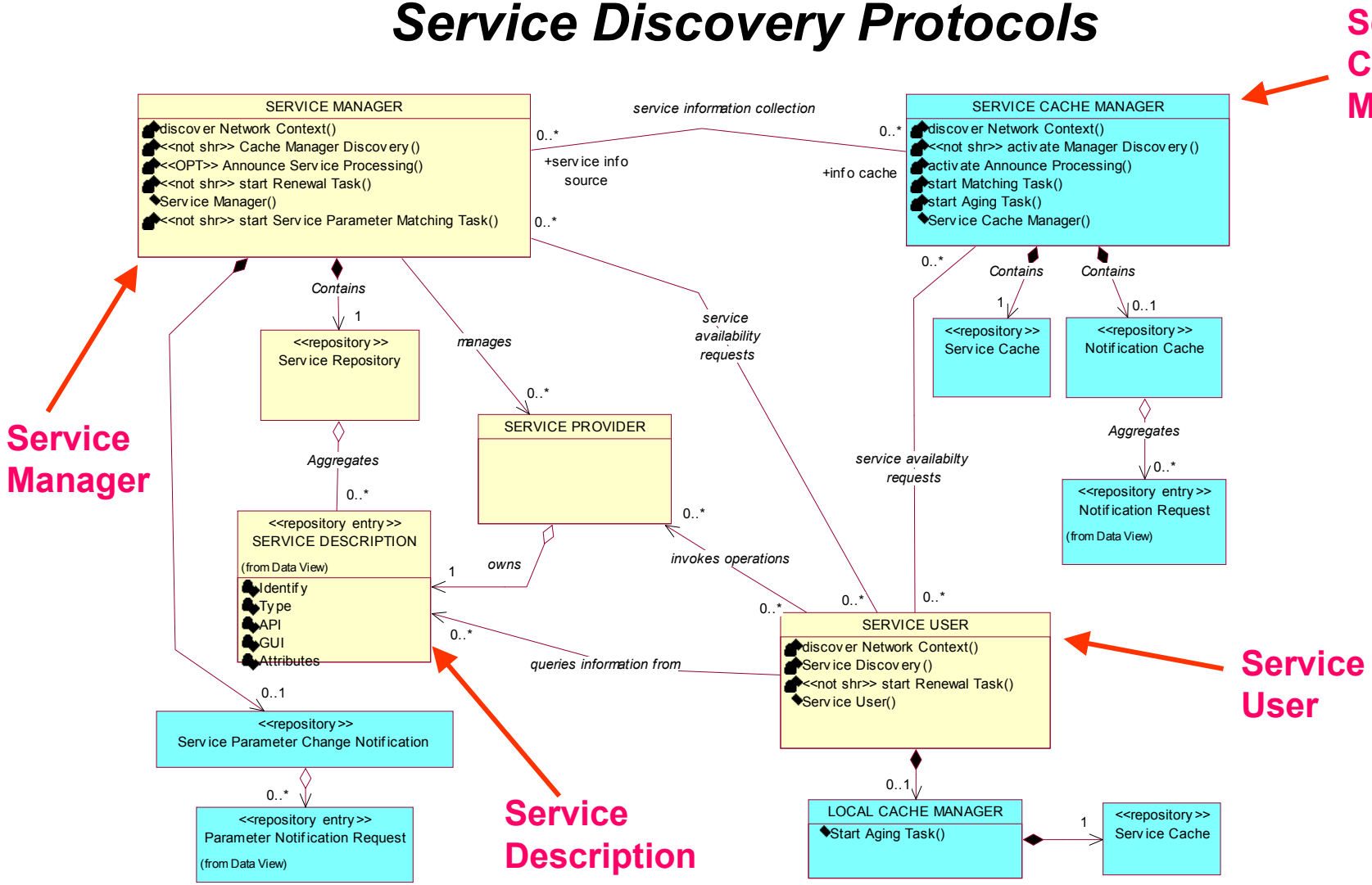
- Define a Generic UML Model that Encompasses Jini, UPnP, SLP, HAVi, and Bluetooth Service Discovery and that provides a common terminology for discussing discovery protocols, and then derive Specific UML Models for Jini, UPnP, & SLP (expressed in the common terminology)

- From the UML models and the specifications, encode executable *Rapide* models of the structure and behavior of Jini, UPnP, & SLP

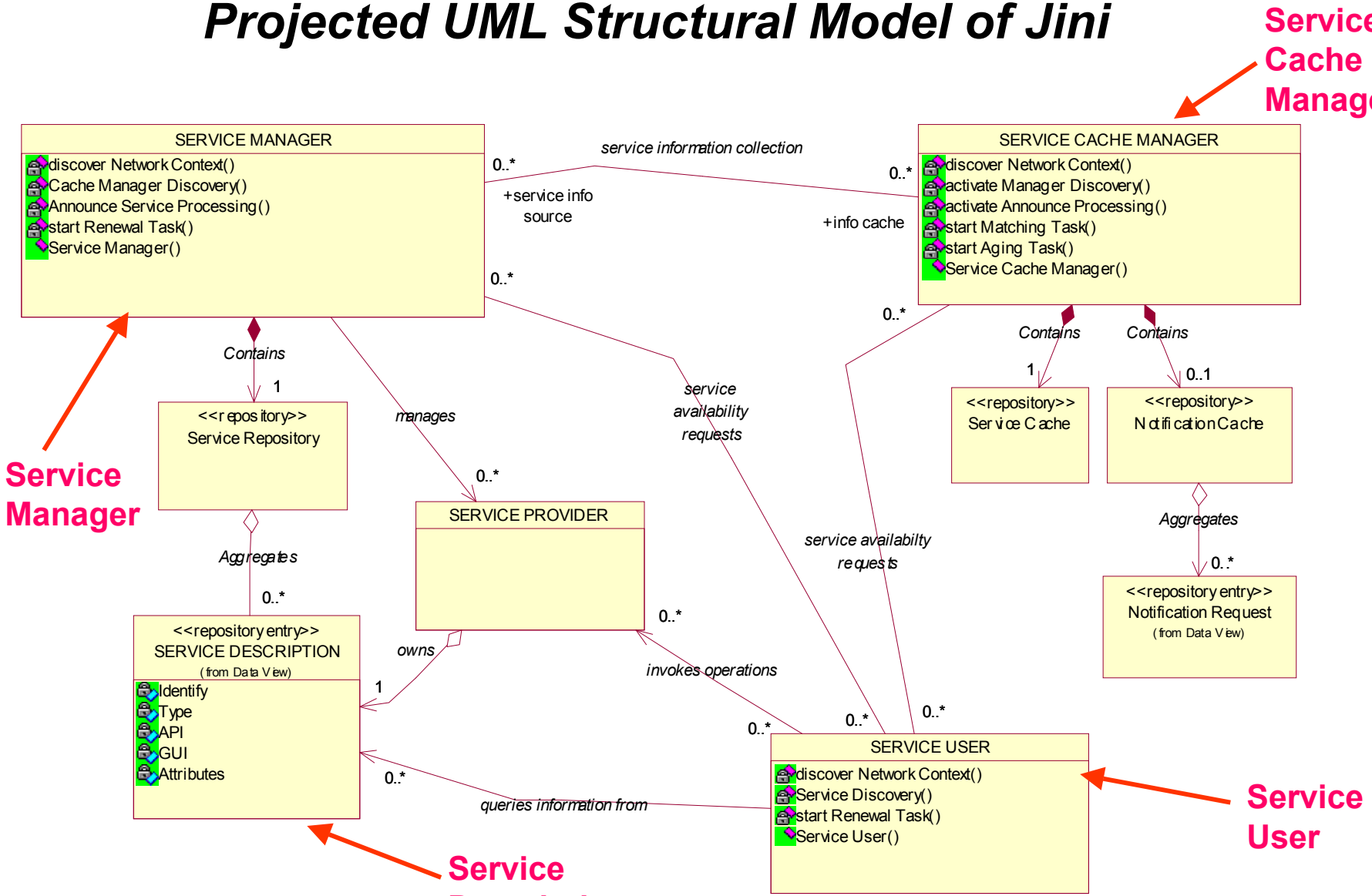
- Define consistency conditions and constraints that should be satisfied by discovery protocols in general and by specific discovery protocols, and define some behavioral metrics

- Define a scenario language and scenarios to drive the executable models, and then exercise the models while evaluating satisfaction of consistency conditions and constraints and assessing the behavior exhibited by the executable models

Generic UML Structural Model of Service Discovery Protocols



Projected UML Structural Model of Jini



Architecture Description Languages and Tools

Allow us to **model the essential complexity** of discovery protocols, while ignoring the incidental complexity

Jini is documented in a 385 page specification; however, the static nature captures only the **normative complexity** because most of the **essential complexity** arises through interactions among distributed, independently acting Jini components.

Incidental complexity represented by the code: for example consider Core Jini – an 832 page commentary on the massive amount of Java code that comprises Jini, which also depends on complex underlying code for Remote Method Invocation, Distributed Events, Object Serialization, TCP/IP, UDP, HTTP, and Multicast Protocol Implementation.

Architectural Description Languages

- Provide effective abstractions for representing and analyze software architectures (components, connections, behavior, constraints, etc.)
  - Using Rapide (Stanford) because of POSET paradigm & constraint language
- ADLs provide a framework and context
  - to more easily **pinpoint** where **inconsistencies and ambiguities** may exist within software implementing specifications & to understand how they arise
  - to **define metrics** that yield qualitative and quantitative measures of dynamic component-based software
- ADLs provide basis to **compare and contrast** dynamic discovery **protocols** (Jini, UP&P, SLP)

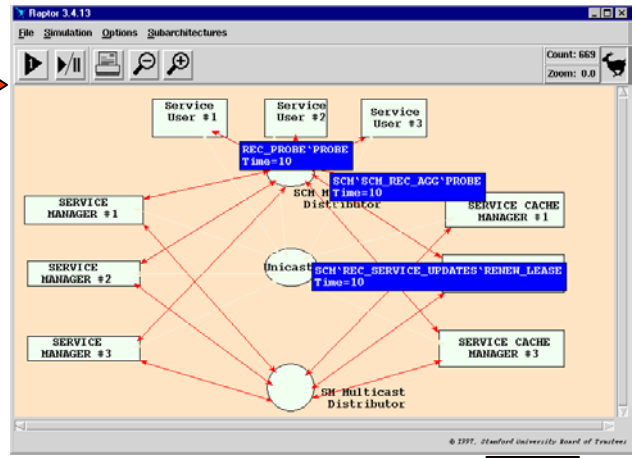
Rapide, an Architecture Description Language and Tools Developed for DARPA by Stanford

MODELING ESSENTIAL COMPLEXITY

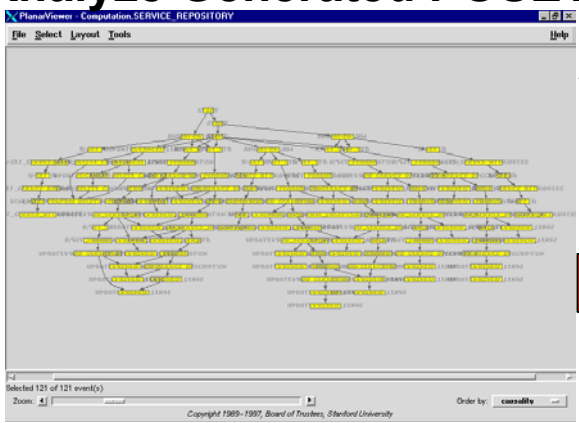
Model Specification in Rapide

```
-- ************************************************
-- ** 3.3  DIRECTED DISCOVERY CLIENT INTERFACE     **
-- ************************************************
-- This is used by all JINI entities in directed
-- discovery mode.  It is part of the SCM_Discovery
-- Module. Sends Unicast messages to  SCMs on list of
-- SCMS to be discovered until all SCMS are found.
-- Receives updates from SCM DB of discovered SCMs and
-- removes SCMs accordingly
-- NOTE: Failure and recovery behavior are not
-- yet defined and need reviw.
TYPE Directed_Discovery_Client
  (SourceID : IP_Address; InSCMsToDiscover : SCMList; StartOption : DD_Code;
   InRequestInterval : TimeUnit; InMaxNumTries : integer; InPV : ProtocolVersion)
IS INTERFACE
SERVICE DDC_SEND_DIR    : DIRECTED_2_STEP_PROTOCOL;
SERVICE DISC_MODES      : dual SCM_DISCOVERY_MODES;
SERVICE DD_SCM_Update   : DD_SCM_Update;
SERVICE SCM_Update      : SCM_Update;
SERVICE DB_Update       : dual DB_Update;
SERVICE NODE_FAILURES : NODE_FAILURES;  -- events for failure and recovery.
ACTION
 IN Send_Requests(),
    BeginDirectedDiscovery();
BEHAVIOR
   action animation_Iam (name: string);
   MySourceID        : VAR IP_Address;
   PV                : VAR ProtocolVersion;
```

Execute with Raptor Engine

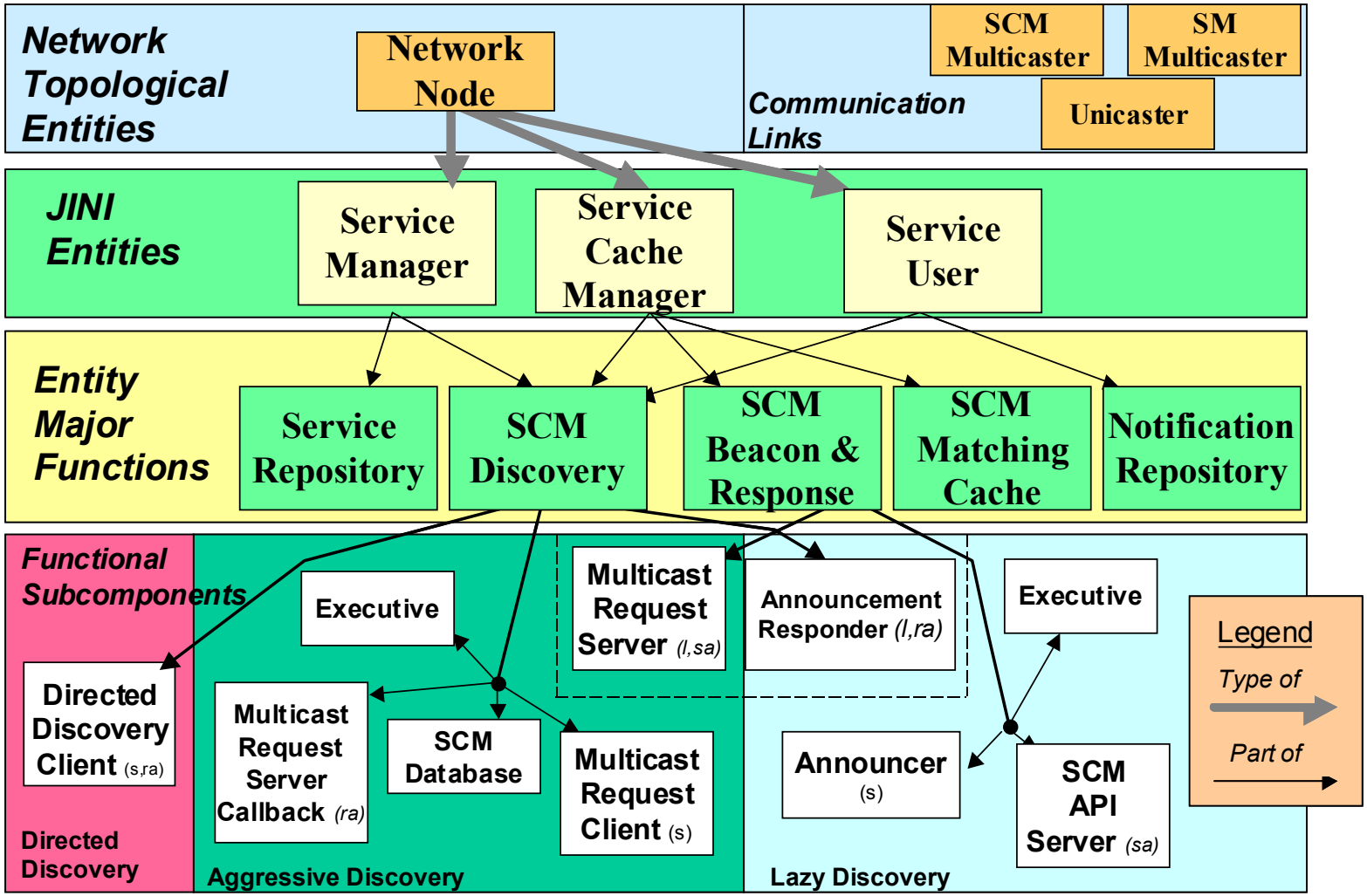


Analyze Generated POSETs

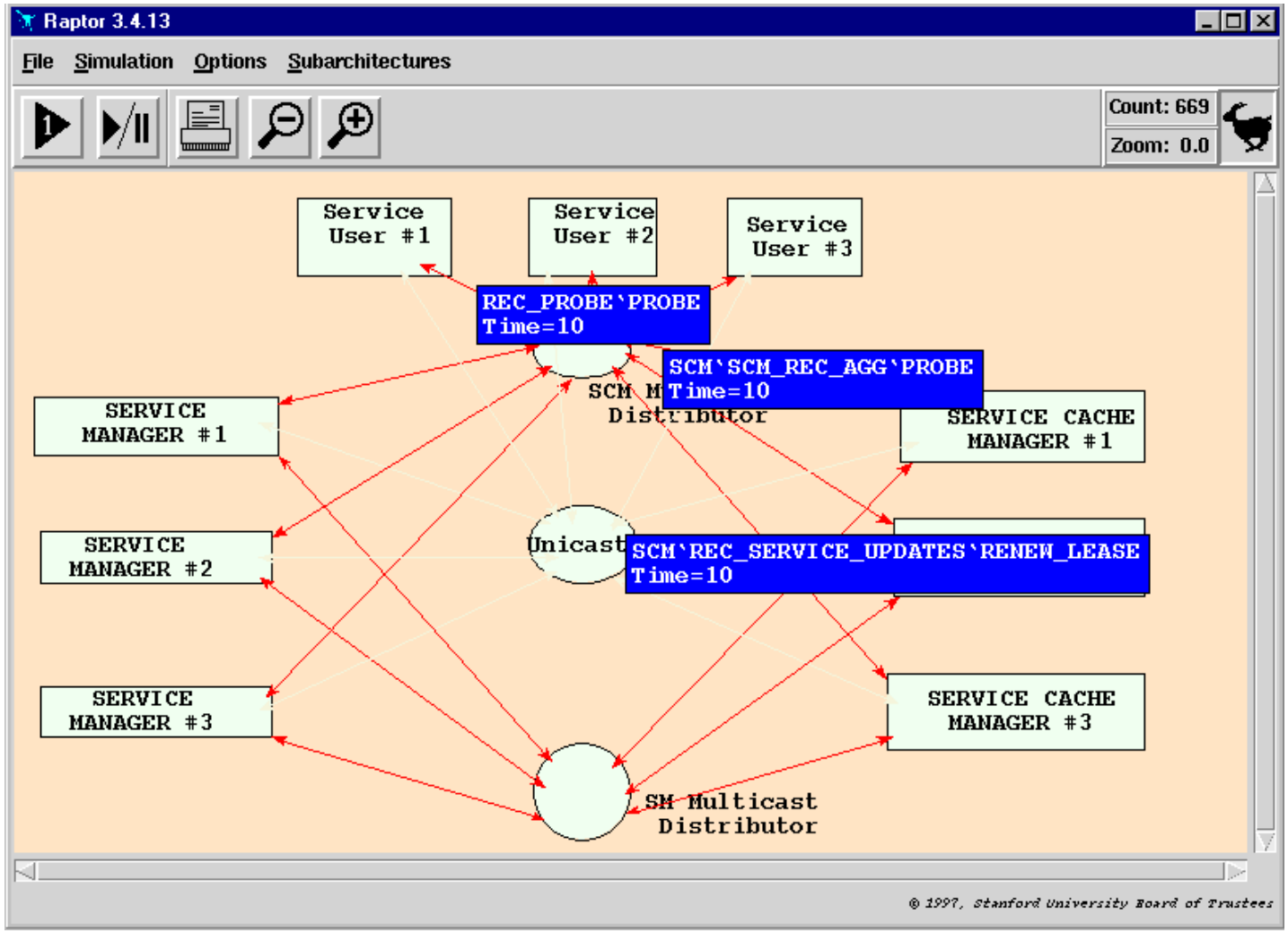


Assess Consistency Condition Satisfaction & Constraint Violations

Define Executable JINI Architectural Model in Rapide



Deploy Instances of Jini Entities and Communication Channels in a Topology



Drive Model Topology with Scenarios

> StartTime {NodeFail || NodeRecover} NodeID DelayTime.
> StartTime {LinkFail || LinkRestore} NodeID DelayTime FromNode ToNode.
> StartTime {MProbeFail || MProbeRestore} NodeID DelayTime FromNode ToNode.
> StartTime {GroupJoin || GroupLeave} NodeID DelayTime.
> StartTime {AddSCM || DeleteSCM} NodeID DelayTime.
> StartTime {AddService ChangeService}NodeID DelayTime ServiceTemplate ServiceAPI ServiceGUI LeaseTime DurationTime.
> StartTime DeleteService NodeID DelayTime ServiceID.
> StartTime FindService NodeID DelayTime SMNodeID .
> StartTime AddNotificationRequest NodeID DelayTime NotificationID ServiceTemplate Transitions LeaseTime DurationTime SCMID.
> StartTime DeleteNotificationRequest NodeID DelayTime NotificationID SCMID.

Analyze Consistency Condition Satisfaction in Real-Time

Sample Consistency Conditions*

For All **(SM, SD,SCM): (SM,SD)** ***IsElementOf*** **SCM registered-services**
implies **SCM** ***IsElementOf*** **SM discovered-SCMs**

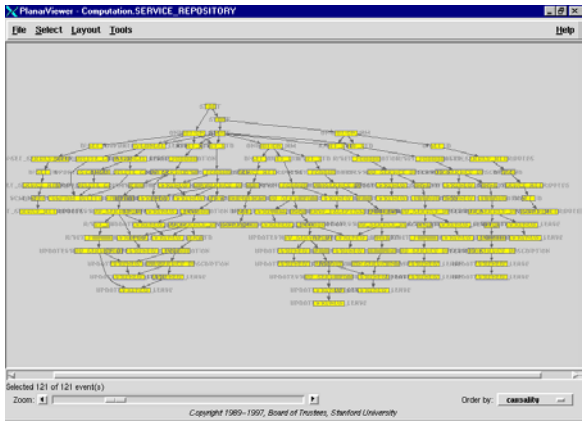
For All **(SU,NR,SCM): (SU,NR)** ***IsElementOf*** **SCM registered-notifications**
implies **SCM** ***IsElementOf*** **SU discovered-SCMs**

***Assuming absence of network failure and normal delays due to updates**

- SM is Service Manager
- SD is Service Description
- SCM is Service Cache Manager
- SU is Service User

- NR is Notification Request
- Registered-services is a set of (SM,SD) pairs
- Registered-notifications is a set of (SU,NR) pairs
- Discovered-SCMs is a set of SCM

Analyze POSETs Off-Line to Compare and Contrast Behaviors Given a Congruent Topology and Scenario



Metrics Based on Numbers of Messages
- Message volume?
- Message intensity?

Metrics Based on Complexity
- Degree of dependency among messages?
- Rate of consistency & constraint violations?
- Rate of exceptions?

Metrics Based on Time
- Service latency?
- Service throughput?
- Recovery latency?

Metrics Based on Change
- Derivative of the message intensity?
- Derivative of the service throughput?
- Derivative of the service latency?

POSET analyses provide basis for defining *metrics* that provide quantitative measures of properties of a system

Where do we stand now?

- Developed an initial UML model of a generic service discovery protocol with specific projections for Jini, UPnP, and SLP
- Developed and exercised an executable *Rapide* model of the Jini, including some consistency conditions, constraints, behavioral metrics
- Providing developers of Jini (and of other protocols) with results of analysis
- Working on a paper to describe our goals, approach, and interim results, and to provide recommendations for improving and using ADLs.

What's to come?

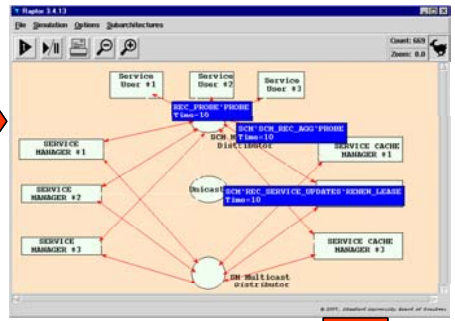
- Develop, exercise, and analyze executable specifications for Universal Plug-and-Play (UPnP) and Service Location Protocol (SLP)
- Provide a technical comparison among Jini, UPnP, and SLP

Questions?

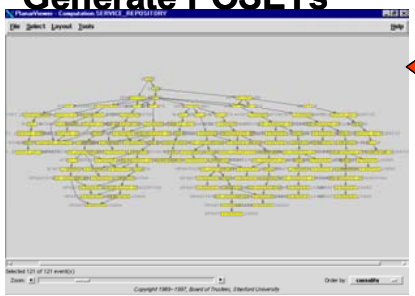
Rapide Model of Jini V1.1

```
-- ************************************************************
-- ** 3.3  DIRECTED DISCOVERY CLIENT INTERFACE     **
-- ************************************************************
-- This is used by all JINI entities in directed
-- discovery mode.  It is part of the SCM_Discovery
-- Module. Sends Unicast messages to  SCMs on list of
-- SCMS to be discovered until all SCMS are found.
-- Receives updates from SCM DB of discovered SCMs and
-- removes SCMs accordingly
-- NOTE: Failure and recovery behavior are not
-- yet defined and need reviw.
TYPE Directed_Discovery_Client
  (SourceID : IP_Address; InSCMsToDiscover : SCMList; StartOption : DD_Code;
   InRequestInterval : TimeUnit; InMaxNumTries : integer; InPV : ProtocolVersion)
IS INTERFACE
SERVICE DDC_SEND_DIR    : DIRECTED_2_STEP_PROTOCOL;
SERVICE DISC_MODES      : dual SCM_DISCOVERY_MODES;
SERVICE DD_SCM_Update   : DD_SCM_Update;
SERVICE SCM_Update      : SCM_Update;
SERVICE DB_Update       : dual DB_Update;
SERVICE NODE_FAILURES : NODE_FAILURES;  -- events for failure and recovery.
ACTION
 IN Send_Requests(),
    BeginDirectedDiscovery();
BEHAVIOR
   action animation_Iam (name: string);
   MySourceID        : VAR IP_Address;
   PV                : VAR ProtocolVersion;
```

Execute with Raptor Engine



Generate POSETs



If you want see a demo, then please let me know?

cdabrowski@nist.gov